Ecopath with Ecosim Workshop

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ECOPATH with ECOSIM Workshop Summary
and
Ecosystem Modeling Recommendations

Executive Summary

Multi-species fisheries management has recently been adopted as a primary focus for fisheries and shellfisheries of the Chesapeake Bay, as an alternative and complementary effort to single species modeling and management that has dominated fisheries plans for the last several decades. To begin this process for the Chesapeake Bay, NOAA's Chesapeake Bay Office working through the Chesapeake Bay Stock Assessment Committee has initiated a working agreement with the research community responsible for development, application, and distribution of the predator-prey ecosystem modeling program known as ECOPATH. Developed at the University of British Columbia, the ECOPATH software provides qualitative assessments of the impacts of various fisheries (and other) management options in a suite of ecosystems by quantifying predator-prey relationships of the dominant functional groups in each environment.

An ECOPATH with ECOSIM (EwE) Workshop was held at the National Wildlife Center in Laurel, Maryland from October 22-24, 2001. Sponsored by NOAA's Chesapeake Bay Office and hosted by the Chesapeake Research Consortium, members of the research, management, and agency communities convened to become familiarized with NOAA's Bay Office long-term goals for multi-species fisheries management and in the short-term, the ECOPATH model. The latter activity included assigning model variables needed for a first approximation of a Chesapeake Bay ECOPATH model, identifying biomass in trophic groups from plankton to top piscivores in the Chesapeake Bay, list potential policy options for fisheries to be considered in responding to the recently adopted Chesapeake 2000 agreement, and identify members of the various communities who might assist in model development, guidance, and oversight in the coming year.

The workshop derived the following products needed for beginning the NOAA Bay Office activities in the coming year. First, following focused discussion and recommended approximations of data and model variables, a first-cut balanced ECOPATH model was derived. Second, a list of policy options for model exploration was derived. Third, an oversight advisory panel and workgroups for critical areas of the model's application were recommended. Fourth, an outline of the NOAA Chesapeake Bay Office agenda and support was presented to ensure community involvement. And fifth, the importance of multiple modeling approaches, in addition to ECOPATH, for estimating policy options in future Chesapeake Bay fisheries assessments was adopted by all meeting participants.

Single-species modeling is still the norm for most regions of the coastal U.S. With the expanding recognition of the importance of multispecies fisheries management, the EwE workshop results are important for undertaking first steps in multispecies management in

the Chesapeake Bay region. Hopefully, through active model development and refinement in an expanding collaboration among the NOAA Chesapeake Bay Office and the regional research and management communities, a list of potentially useful and acceptable management scenarios might be derived and prioritized to meet the Chesapeake 2000 goals for 2004 to 2010.

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Document Content

This document summarizes the proceedings and outcomes of the ECOPATH meeting as well as the initial accomplishments. It also sets the stage for subsequent development of the model in the Chesapeake Bay, addressing concerns specific to this region and to local scientists, managers, and agency staff. Further, this document outlines the next steps in ECOPATH model evolution including the organizational management structure, prerequisites for success, and tasks for the immediate future. The latter material serves as recommendations for future Ecosystem Modeling activity within the NCBO-administered modeling program.

ECOPATH with ECOSIM Workshop Summary
and
Ecosystem Modeling Recommendations

Introduction

Multispecies fisheries management in the Chesapeake Bay is a high priority for the management community of the region. The concept was the topic of the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) workshop in 1998 and recommended in the resulting STAC report, "*Prospects for Multispecies Fisheries Management in Chesapeake Bay*." With that guidance, NOAA's Chesapeake Bay Office (NCBO) and the Chesapeake Bay Stock Assessment Committee (CBSAC) have initiated several projects to begin multispecies management options that will complement historically dominant single species management plans common to the Bay and most other coastal regions of the U.S. This effort must specifically address fish and shellfish requirements for the next decade as listed in the Chesapeake 2000 agreement (C2K). Hence, it is critical to develop assessment techniques to assist regional managers in prioritizing policy options that might be applied to reasonably approach the goals of the agreement.

Through one of these projects, the NCBO is now collaborating with the University of British Columbia for application of an established carbon based ecosystem model ECOPATH (http://www.ecopath.org) in the Chesapeake Bay. ECOPATH modeling is one of several approaches for providing tools to assess the impact of various management policies for Bay water quality and individual fisheries on ecosystem response. In an effort to assemble the critical data sets required for generation of a Chesapeake Bay ECOPATH model, the NOAA Chesapeake Bay Office (NCBO) and the Chesapeake Research Consortium (CRC) convened a regional workshop.

The ECOPATH and ECOSIM (EwE) Workshop provided an opportunity to explore extended collaboration between the NCBO, research community, and managers of our coastal resources in applying the model to the Bay's resource stocks. It provided a forum for presentation of the model, development of biomass and rate functions for predator and prey of a specific Chesapeake Bay ECOPATH model, and open discussion of policy options whose impact might be predicted from application of the Bay ECOPATH model. Additionally, recognizing the need for open access to model application and use, the NCBO requested community recommendations for modeling oversight. To ensure agency, researcher, and manager collaboration, NCBO outlined specific policies it would implement to ensure community involvement, support, and model usage.

ECOPATH & ECOSIM

Model Descriptions

ECOPATH, as a static mass balance model, requires identifying and quantifying feeding relationships between various living resource stocks in an aquatic system. The feeding relationships require estimates of biomass of each living resource and feeding rates of a predator on a prey item or group. Mortalities from predation as well as harvest and any other death terms are also important to 'predicting' yields of each trophic level; factors that alter these trophic levels can be assessed for impacts on any organism or group of the ecosystem. These factors, for example, might be the management policies that can be applied in the system (fishing limits, gear types, etc.) or natural control through events such as storms, hurricanes, disease, and parasitism.

As a static model, ECOPATH can provide single point-in-time estimates of carbon flow through food webs of a given ecosystem. More important to long-range management options, however, is the inclusion of time and space dynamics. This is accomplished through two other components of the modeling effort, ECOSIM (temporal dynamics via dynamic simulations) and ECOSPACE (a spatial dynamic model). ECOSIM incorporates time-series data of known mortality rates, catches, and effort. This approach predicts changes in mortality rates through time. With this capability, management policy can then be based on or explored through model simulations. Spatial applications of simulations is accommodated through ECOSPACE where ECOSIM dynamics are applied over a grid of homogeneous cells. The cells are linked by dispersal, fishing effort, movement, and allocation. ECOSPACE ultimately predicts the spatial distribution of aquatic animal species and can be used to address stock responses to specific options such as establishing protected areas or changing habitat.

The Chesapeake Bay ECOPATH with ECOSIM Workshop

The Meeting

Approximately 70 registrants participated in the EwE Workshop in at the National Wildlife Center in Laurel, October 22-24, 2001. Registration packets contained an instruction manual for ECOPATH, a CD with model, and general registration materials.

Opening Plenary Session

The meeting convened in a plenary session with UBC modelers responsible for ECOPATH model development and application discussing its uses and capabilities, and successes and failures in other ecosystems where the model has been applied. They provided an overview of the basic assumptions and approaches of the ECOPATH model. The basis for ECOPATH is two master equations for predator-prey interactions, and requires specific data requirements for development of a balanced model. The two master equations for ECOPATH are:

ECOPATH Equation #1:

Production = predation + fishery harvest + biomass accumulation + net migration + other mortality

ECOPATH Equation #2:

Consumption = production + respiration + unassimilated food

Variables used in the model are found in Table 1. Estimating these parameters is a central requirement for developing a balanced model, a prerequisite for exploring suites of management options and their impacts throughout the living resources of the Bay.

Table 1. Abbreviations for model variables

Model Variable	**Abbreviation**	**Descriptor**
Biomass	B	t/km^2
Production/Biomass	P/B	Total mortality rate
Consumption/Biomass	Q/B	Food intake normalized to group biomass
Ecotrophic Efficiency	EE	% Production used in system
Production/Consumption	P/Q	~Gross food conversion efficiency
Biomass Accumulation	BA	Biomass accumulation rate
UnassimilatedFood/Consumption	U/Q	Non-assimilated food/intake
Production/Respiration	P/R	Fate of assimilated food
Respiration/Consumption	R/Q	% Assimilated food lost to non tissue growth to total intake
Respiration/Biomass	R/B	Expression of group activity
Consumption	Q	Total consumption rate
Respiration	R	Assimilated food - production
Production	P	Tissue increase
Unassimilated Food	U	Feces, urine
Trophic Level	TL	Index of trophic level in prey preference
Omnivory Index	OI	Degree of feeding specialization, 0=feeds on 1 trophic level, with increasing omnivory as index increases

Several key characteristics of the ECOPATH and accompanying models were outlined during the fist day's presentations. One, ECOPATH and its accompanying models, permit estimating impacts of specific 'stressors to the system, such as fishing, environmental change, bioaccumulation and impacts of pollutants, evaluation of marine protected area effectiveness, and uncertainties in management options. Two, there is open source code for the mass balance, time invariant, non-steady state ECOPATH model, permitting general use. Three, results will be annual approximated over the entire Bay, and over the entire water column (no vertical structure). Four, the data quality used in the model is documented, providing a data 'pedigree' to provide a means to estimate confidence levels for output. Annual totals as wet weight are required. Although a good international resource is FishBase (http://www.fishbase.org), 'local' data is best. Five, age structure is accommodated with two life stages, juvenile and adult or by using migration to/from a cell/area. Six, flux from prey to predators is determined through assigned vulnerabilities and diet preference of the predators. Seven, bottom-up impacts, e.g., through water quality components such as nutrients or water clarity, are not coded in the models. Their impacts can be included through modifying primary production in the model or adjusting vulnerability of the primary producers to predation; water clarity also impacts visual predator success so vulnerability of prey to visual feeding predators can also be adjusted. Lastly, sensitivity runs can be performed to reproduce community changes that have been observed historically or spatial gradients that are known to exist. The ECOPATH website (http://www.ecopath.org) or the user manual, "*Ecopath with Ecosim: A User's Guide*," provides additional details.

Management and Public Policies Related to Use of ECOPATH

As a primary goal of the workshop, the participants were asked to list management policies that might be explored in a developed Chesapeake Bay ECOPATH model, with a requested focus on the restoration goals of the C2K agreement. According to model developers, a good ECOPATH model will correctly order and prioritize policy choices, assisting local and regional officials and community members in allocating resources and political will to specific management scenarios and not others.

The following potential policy questions for driving ECOPATH model application were identified during the meeting. The questions represent a first attempt at pinpointing the most pressing management needs and will be modified through the coming months as the model process continues.

1. What are the ecohabitat and fishery impacts of increases or decreases in nutrient loading, dissolved oxygen (DO), and turbidity?
2. What are the consequences of a tenfold increase in the oyster population in the Chesapeake Bay?
3. Should we stop fishing menhaden in the Chesapeake Bay versus outside the Bay?

4. What are the nutrient impacts of increases or decreases in fishing, particularly for filter feeders?
5. Is game fish restoration appropriate given the status of mid-chain forage fish stocks?
6. Can water quality (e.g., DO) be managed by top-down actions such as fishery regulations?
7. Are there too many striped bass in the Chesapeake Bay?
8. What is the optimal configuration of harvest in terms of rent?
9. What would happen to the ecosystem if sea grasses could be restored (specifically addressing turbidity and nutrients)?
10. Would increases in freshwater input reduce oyster disease mortality?
11. What is the relative importance of climate variation on fish populations versus that of harvesting pressure?
12. Can the crab stock be restored through fishery reductions and the use of protected areas?
13. Can the crab stock be increased by the "control" of other mortality agents, particularly predators?
14. Can protected areas for oysters enhance abundance and aid in their restoration?
15. What defines a healthy Chesapeake Bay ecosystem? Is there consensus on what it would mean to successfully manage that ecosystem? What are the trophic limits to the configuration of that system?
16. Have fishery or habitat changes caused changes in the ratio of gelatinous organisms to fish? Does this ratio represent a stable alternate state?
17. Have increases in high-frequency variability in primary productivity (blooms?) contributed to increases in gelatinous organisms?
18. Has the removal of stream barriers to anadromous fish spawning allowed increases in shad, herring, or bass, or are these fish just food for the exotic predators (such as large mouth, small mouth bass, and catfish) upstream of the barriers? Would the same thing happen if additional barriers were removed?
19. What are the effects of waterbird predation on their prey, specifically, and Chesapeake Bay fisheries, generally?
20. What is the role of forage fish in Chesapeake Bay ecosystem dynamics?
21. Is there an effect of changes in primary production on fish (planktivore) populations?
22. What are the impacts of wetland restoration?
23. What are the implications of migratory piscivores (e.g., bluefish, croaker) on the Chesapeake Bay environment?
24. What is the effect of land management in the Chesapeake Bay watershed on the estuarine food web?
25. What are the effects of aquaculture, species introductions, and hatcheries on the ecosystem?

Data required for addressing these questions included over 40 species or functional groups. Table 2 shows the species and groups identified and evaluated at the workshop for use in the Chesapeake Bay ECOPATH model.

Modeling flow between these groups and changes within a group mandate that specific data sets and fluxes be included in the modeled relationships. The variables will comprise, but not be limited to:

- biomass (relative or absolute)
- catches
- climate change
- consumption rates
- diets
- effort
- employment
- fleets
- migration
- mortality rates
- prices/costs
- productivity patterns
- time series

As the lists (species and variables) represent suggestions by the EwE participants, it was recognized that the lists would change with model exploration and refinement. Hence, meeting leaders recommended that an initial technical report be produced by the model facilitators within six months that contains a revised list of important Chesapeake Bay species and the data on which the model would be based.

Defining Trophic Groups and Rate Functions: Breakout Workgroups

Pre-workshop review of living resource stocks in the Chesapeake Bay indicated that the model might have to include up to 40 species in the Bay's food web. Many data were derived from local and regional resources as well as FishBase (www.fishbase.org) from plankton, to planktivores in the pelagic and benthic communities, to piscivorous birds, nekton, and benthos. Following plenary, three break-out groups met to discuss biomass, mortalities and diet preferences for each group. The groups also compiled lists of experts who might assist in data assembly and discussed the functional relationships between groups. Experts for these groups derived the following list of model needs, as well as standing stocks and food preferences for each species or group.

Lower Trophic Levels: Based on discussion within a limited group of experts, the following recommendations were derived for the initial Chesapeake Bay ECOPATH model:

Table 2. Workshop-generated species and group list for use in the Chesapeake Bay ECOPATH model.

Group Name	**Habitat Area (fraction)**	**Biomass in Area (t/km^2)**	**P/B (/yr)**	**Q/B (/yr)**	**EE**	**P/Q**	**+/- Biomass ($t/km^2/yr$)**	**U/Q**	**Detritus Import ($t/km^2/yr$)**
Picivorous birds	1	0.028	0.1	30			0	0.2	
Ducks	1	0.5	0.2	30			0	0.2	
Black seabass	1	0.001	0.74	3.6			0	0.2	
Spot	1		1.82	18	0.95		0	0.2	
Striped bass (adult)	1		0.47	1.4	0.95		0	0.2	
Striped bass (juv.)	1		1.5	2	0.95		0	0.2	
Weakfish (adult)	1		0.98	3.5	0.95		0	0.2	
Weakfish (juv.)	1	0.01	3	4			0	0.2	
Bluefish (adult)	1		0.61	4.6	0.95		0	0.2	
Bluefish (juv.)	1	0.001	2.4			0.25	0	0.2	
Reef association demersal fish	1	0.1	0	9.857			0	0.2	
Summer flounder	1	0.1	0.6	4.1			0	0.2	
Atlantic menhaden (adult)	1	30	1.55	31.4			0	0.2	
Atlantic menhaden (juv.)	1	2	4.7	32			0	0.2	
Atlantic croaker	1		0.47	7.34	0.95		0	0.2	
Black drum	1		0.4	1.8	0.95		0	0.2	
Red drum	1		0.5	2.2	0.95		0	0.2	
Spotted seatrout (adult)	1	0.006	0.7	6.76			0	0.2	
Spotted seatrout (juv.)	1	0.002	2.1	7			0	0.2	
Pelagic forage fish	1		0.8	5	0.95		0	0.25	
Alewife/herring	1		0.9	8.62	0.95		0	0.2	
American eel	1		0.4	3	0.95		0	0.2	

American shad	1	0.077	1.5	3.7			0	0.2	
Bay anchovy	1	4.8	4			0.3	0	0.2	
Channel catfish	1		0.7	2.6	0.95		0	0.2	
Hickory shad	1	0.001	1	10.1			0	0.2	
Other flatfish	1	0.02	0.8	2			0	0.2	
Hogchoker	1	0.003	0.6	4			0	0.2	
White perch (adult)	1		0.5	3.8	0.95		0	0.2	
White perch (juv.)	1		1.5	4	0.95		0	0.2	
Yellow perch	1		0.5	2.79	0.95		0	0.2	
Cobia	1	0.001	0.3	5			0	0.2	
Cownose rays	1	0.5	0.15	5			0	0.2	
Group Name	**Habitat Area (fraction)**	**Biomass in Area (t/km^2)**	**P/B (/yr)**	**Q/B (/yr)**	**EE**	**P/Q**	**+/- Biomass ($t/km^2/yr$)**	**U/Q**	**Detritus Import ($t/km^2/yr$)**
Gizzard shad	1	0.355	0.6	5			0	0.2	
Blue catfish	1	0.008	0.2	5			0	0.2	
Non-reef demersal fish	1	0.1	0.2	5			0	0.2	
Sandbar shark	1	0.001	0.1	5			0	0.2	
Turtles	1	0.003	0.1	4			0	0.2	
Terrapins	1	0.008	0.15	4			0	0.2	
Hard clam	1	5	0.5	23			0	0.2	
Non-commercial	1	118	2			0.25	0	0.2	
Other demsersal in/epifauna	1		3.5		0.95	0.2	0	0.2	
Mesozooplankton	1		40		0.95	0.2	0	0.4	
Microzooplankton	1		140		0.95	0.2	0	0.4	
Ctenophores	1	20	6	30			0	0.2	
Sea nettles	1	0.2	3	80			0	0.2	

Blue crab (adult)	1		1.275		0.95	0.25	0	0.2	
Blue Crab (juv.)	1		3.75		0.95	0.25	0	0.2	
Horseshoe crab	1	0.001	2			0.25	0	0.2	
Oyster	1		2		0.95	0.25	0	0.2	
Soft clam	1		2		0.95	0.24	0	0.2	
Phytoplankton	1	95			0.95		0		
Cyanobacteria	1	3	80				0		
SAV	1		7.3		0.7		0		
Benthic algae	1	25	80				0		
Detritus	1						0		142.35

- Three groups, diatoms, cyanobacteria, and others, should be considered in the ECOPATH model to mirror the Chesapeake Bay Program (CBP) model. Regional experts include Kevin Sellner (CRC), Richard Lacouture (Academy of Natural Sciences), Harold Marshall (Old Dominion University) with data available from Jacquelin Johnson (Interstate Commission on the Potomac River Basin/NCBO).
- Loss terms (P/B) for phytoplankton and zooplankton for use in the model could be provided by the CBP models (Lewis Linker, CBP).
- Data for submerged aquatic vegetation (SAV, biomass and P/B) can be obtained from the CBP. Robert Orth (Virginia Institute of Marine Sciences) has supplied the data and is the regional expert.
- Proposed experts for providing lower trophic level information are Claire Buchanan (Interstate Commission on the Potomac River Basin (ICPRB)) and Jacqueline Johnson (ICPRB/NCBO) for the micro- and mesozooplankton and Michael Roman (University of Maryland Center for Environmental Science, Horn Point Laboratory) for mesozooplankton.
- ECOPATH and CBP model results should be compared, and UBC and CBP (L. Linker, CBP) representatives agreed to do so.
- The group decided that seasonal EwE models should be considered as an alternative to the annual EwE model output if annual patterns indicate a shortcoming. The prospect of using a seasonal EwE model that is in development at UBC was discussed and offered for consideration pending publication of the model.
- Researchers could examine separate zones in the Chesapeake Bay after the overall Bay results are finalized, emigration and immigration are better understood, and procedures are identified for estimating consumption of prey from outside established boundaries.
- Researchers need to verify the consumption and biomass for zooplankton.
- Data from the TIES Program (Trophic Interactions in Estuarine Systems; UMCES, Chesapeake Biological Laboratory) should be collected using the TIES website (James Hagy, expert).

Middle Trophic Levels: This is a group of organisms (Table 3) that overlap the lowest and highest trophic levels. Recommendations include:

- Researchers need to ensure that all commercial species remain separate (ungrouped) and that data for these species are accurate. Non-commercial species, however, may be grouped, particularly if they are members of the same functional group.
- Zooplankton presents a unique problem due to variability in a dynamic environment leading to a range of consumption and survival rates for different fish species. Zooplankton might be differentiated into groups based on upper trophic

Table 3. Middle Trophic Level input on species for the Chesapeake Bay ECOPATH model.

Species	**m t/km^2**	**P/B**	**Q/B**	**P/Q**	**m tons**	**Provider**	**Comments**	**Contact**
Picivorous Birds	0.01966				284	Forsell		Forsell
Invert Birds	0.02255				240	Forsell		Forsell
Spot								Bodulus
Striped Bas (juv.)								Austin, Uphoff
Weakfish (juv.)								Brandt (NOAA)
Demersal fish	0.073						Blennies, gobies, hake, oystertoads, skilletfish	Breitburg
Atlantic menhaden	26.3				280,000	Uphoff		Wood, Uphoff
Atlantic menhaden (juv.)								Wood
Atlantic croaker (juv.)	0.7							Chittenden
Forage Fish	0.4					Wood	Silverside, killifish	Wood
Alosa								Olney
Bay anchovy	4.86	11.57				Wood		Wood
Perch								Piavis. Austin
Perch (juv.)								Piavis, Austin
Hard Clam	5					Schaffner		Schaffner
Soft Clam	0.35					Lipcius, Schaffner		Lipcius
Oysters	0.02							Jordan, Wesson
Hogchoker	2.8						Estimated as twice biomass of	

							crabs	
Other benthic filter feeders	15	3				Schaffner		Schaffner
Mesoplankton	2.352					Buchanan		Buchanan, Burton, Carpenter, Roman
Ctenophores	58.8?					Buchanan		Breitburg
Cnidaria	10.8?					Buchanan		Breitburg
Blue Crab	1.428					Lipcius		Lipcius
Blue Crab (juv.)	0.055					Lipcius		Lipcius
Rotifer (microzooplankton)	0.798					Buchanan		Buchanan, Sellner, Coats
Phytoplankton	98.7					Buchanan		Buchanan
Non-commercial suspension feeders	118					Schaffner		Schaffner

level benefits and some species might also serve as important water quality indicators and may need to be included as separate entities.

- Water birds may present problems due to their seasonal nature and the variability of their consumption rates and food choices. Good seasonal biomass averages may alleviate such problems.
- A food web diagram was suggested as the best means of ensuring true-to-life trophic exchange and coverage representations. This approach may also be the best means of subdividing groups and creating functional groups.
- If the biomass of a managed species is currently too small to appear important in the model, the scale of the model area can be changed to magnify the importance of that species.

Table 3 shows the updated information with suggested species or group biomass, names of providers, and experts who can provide more accurate numbers. This table is not precise; it represents only the initial attempt to pinpoint numbers for each group listed. The suggested experts in the last column should be contacted to amend the numbers as required.

Higher Trophic Levels: This group concentrated on defining the area of the Bay for the model, defining and converting data, and evaluating the initial species list. The highlights of the session are as follows:

- UBC facilitators recommended that data be provided as a Bay total (tons per unit area). Density estimates multiplied by the usable area will yield the species total. Specifics are in the ECOPATH manual (*Ecopath with Ecosim: A User's Guide*) provided to all participants.
- The group agreed to an estimate of 10,000 square kilometers as the area of the Bay.
- UBC staff recommended that one simple way to acquire data is to request all data as total Bay biomass, calculate Bay totals, then divide by 10,000 (the estimated Bay area). In cases which indicate a strong trend, best estimates of the current year along with the estimate of annual biomass change will allow ECOSIM to calculate the species' sensitivity to fishing.
- UBC researchers recommended that high-profile fish of special concern or of recreational value, such as sturgeon, red drum, and cobia, be included.
- Seasonality is accommodated by entering the diet composition and the proportion of total food intake coming from outside the system (the food import fraction).
- Major changes and additions to the initial species list were to split jellyfish into ctenophores and sea nettles, and add cobia, cownose rays, sandbar sharks, blue catfish, gizzard shad, sea turtles, terrapins, pelagic forage fish, and littoral forage fish.
- Gary Shenk's (EPA/Chesapeake Bay Program Office) group will provide a Web page for researchers to extrapolate their biomass data to entire salinity zones.

Plenary and An Initial Chesapeake Bay ECOPATH Model

Following discussions on day 2, a "balanced" Chesapeake Bay ECOPATH model was developed using data provided during the workshop, and assumed feeding relationships between predators and prey. This "balanced model" implies that modeled carbon flow between and through groups does not violate basic thermodynamic laws. "Balance," however, does not suggest that the model estimates or results are necessarily correct but to move forward, balancing the model is an important first step.

An initial UBC inspection of the proposed predator-prey linkages suggested that biomass and consumption rate estimates for birds were not correct. The migratory behavior of most species also caused problems, indicating that future models will have to alter diet import components, a problem common to systems where nutrition is gained from outside the modeled system. Some of the initial data entries for biomass estimates or the P/B ratios (e.g., striped bass) which appeared incorrect to the UBC community were altered by the model facilitators; these should be identified by the facilitators in a future document.

The relative success of this initial run allowed the participants to begin examining model dynamics. It was concluded that refinement of data inputs is still required. The UBC researchers emphasized, however, that they have found it more useful at this stage of development to focus on the dynamics of the model rather than on refining inputs.

ECOSIM was introduced, taking the Chesapeake Bay ECOPATH model from a static mass balance to a dynamic simulation. Different model scenarios were run, to introduce the basic model and its output to the participants. The manual received in the registration packet further addressed the specifics of manipulating parameters and running the model.

During discussion of the scenarios, several important considerations and potential problems arose. These issues must be addressed during the Chesapeake Bay model development. Future considerations include:

- Fish mortality: Defining the fishing fleet can be problematic. Often each fleet is assumed to operate evenly for all species. If this assumption is invalid, then gears may be divided into separate fleets. Another assumption is that each fishing fleet has a fixed catchability coefficient which indicates how to optimize the fleet configuration. Economic and socio-economic information is also needed to develop the optimal fleet configuration. Lastly, catch/biomass figures provide an estimate of fishing mortality which can be used along with the catch and a discard function (what is discarded and where it goes).
- A single food as a common food item for many predators may cause some difficulties, particularly if this is not true *in situ*.
- Evaluating the ecotrophic efficiency (EE) can pinpoint omissions in predation or mortality in the model. The EE is the proportion of a species' production that is

used in the system and indicates how much of that species' mortality the model explains. Low EE values may indicate that an ecosystem is vulnerable to invasion; however, it may also indicate that some form of predation, mortality, or disease remains unaccounted.

- Catch numbers constrain the model. The catch mandates the minimum primary production needed to support that number of organisms.
- Feeding consumption by a species outside of the system can cause problems. Model dynamics will likely be unstable if a species' food is outside the system or most of their harvest occurs there. Diet import fractions, as well as out-of-system harvests, must be carefully considered.
- Testing the model for stability will ensure that saddle points in model output do not exist. A saddle point is defined as a situation in which a disturbance causes the system to move to a stationary, more simplified, and less diverse community. If the diet input data realistically represent trophic interactions, saddle points will not exist and the system should be stable to small perturbations.
- Keeping the model simple could be the greatest challenge of all. In previous ECOPATH work, there is a pervasive problem of over-parameterizing the models. A better option is to build several models with different numbers of biomass pools, providing a range of model capabilities that vary with different policy questions.

Workshop Outcome and Recommendations

Proposed Management Structure

Substantial discussion throughout the workshop indicated the overall community concern for model oversight and guidance during model development process. An advisory panel/steering committee was recommended to guide initial model activities. The panel should be composed of closely involved representatives from Federal, state, and academic institutions.

The proposed advisory panel/steering committee for the development of the Chesapeake Bay ECOPATH model is:

Lowell Bahner	National Oceanic and Atmospheric Administration
Derek Orner	National Oceanic and Atmospheric Administration
Harley Speir	MD Department of Natural Resources (MD DNR)
TBD	Chesapeake Bay Program Living Resource staff
TBD	U.S. Fish & Wildlife Service
TBD	Atlantic States Marine Fisheries Commission
Robert Latour	Virginia Institute of Marine Science (VIMS)
Lyle Varnell	Virginia Marine Resources Commission

Steve Murawski	National Marine Fisheries Service, Northeast Fisheries Science Center
Robert Wood	Chesapeake Biological Laboratory
Thomas Miller	Chesapeake Biological Laboratory
Kevin Sellner	Chesapeake Research Consortium

In the post-workshop recommendations, other nominees for the Ecosystem Modeling Advisory Panel included Linda Schaffner, Robert O'Reilly, and Arthur Butt.

In a post-workshop activity, the Fisheries Steering Committee, an advisory group of local and regional fisheries managers, accepted the formation of the Ecosystem Modeling Advisory Panel to oversee the ECOPATH and other modeling efforts and report to the Committee on a regular basis. Kevin Sellner will Chair the Panel.

Workgroups

Four workgroups would also be established to address specific mandates, apportioning the necessary tasks required to create a model that helps meet the C2K goals. The proposed working groups include:

ECOPATH Input Workgroup: (Chair: R. Latour)

Task: Assemble the biomass, production, consumption, and diet composition data for input to the model. This may be implemented within one institution. Alternatively, one skilled data management contractor funded through NCBO can manipulate data identified by researchers in the community and provide this service for all involved institutions rather than hiring individual managers for short periods in each institution. The workgroup might also undertake model articulation and scenario runs.

Fishing Policy Workgroup: (Chair: J. Uphoff, MD DNR)

Task: Articulate policy considerations for fisheries mortality management. The task will involve decisions concerning the types of fishing fleets and approaches to affect fishing policy.

Challenges Workgroup: (Chair: R. Latour, VIMS)

Task: Use historical/time-series data to determine whether the model accurately describes the system. Use the model to recreate historical trends with time-series data.

Water Quality Policy Workgroup: (Co-chair: M. Kemp, UMCES)

Task: Target bottom-up water quality issues and link these to regulatory policies.

Future Model Development

A general summary of needed tasks for future model development and refinement include the following prerequisites, identified by the model developers and participants:

- Good data acquisition is essential; however, complete databases are not required. Data summaries and averages are more useful. There is a risk in over-parameterizing the model.
- Data must be standardized into common units.
- The species (and functional groups) list requires refinement.
- Policy questions generated at the conference must be reevaluated and prioritized.
- A data entry person, who is knowledgeable about the model, must be assigned to enter data and maintain the master database (see ECOPATH Input Workgroup).
- A support contract should be set up for an umbrella organization (possibly CRC) to support administrative functions and pay for travel, research grants, and project logistics.
- The process must remain open and inclusive for the entire Bay community.
- A second-generation model should be prepared for the next workshop (tentatively planned for late March/early April). This workshop will examine the gathered data and will use the model to address some of the policy questions proposed during this workshop. This process will lead to more detailed questions and will narrow the focus for future model development.

Tasks for the Immediate Future

Specific NCBO activities will be initiated to continue the progress made during the workshop. To encourage researchers to provide model input, Bahner proposed NOAA-supported funding for data collections and modeling. It is envisioned that ECOPATH development would be a community endeavor, in which researchers use the model to conduct their own research. Recognizing that data are proprietary and researchers may need to publish collected data prior to providing public distribution of the data, NBCO will encourage use of the model by providing research funding and publication assistance as well as creating working partnerships between NBCO and the research community. To attain this goal, NCBO will designate a coordinator within its office to orchestrate this project. Research funding will likely be committed, pending funding availability, through the CBSAC proposal process following consideration of research and modeling priorities provided by the Fisheries Steering Committee, the Ecosystem Modeling Advisory Panel, and the four workgroups.

To ensure that the ECOPATH modeling process moves forward rapidly and remains open for the entire community, the following tasks must be completed within the next six months:

- NCBO will identify funding to support ECOPATH research, meetings, travel, and publication and appoint an administrative overseer to apportion funds for these purposes.
- NCBO and others will establish a modeling advisory panel (proposed and accepted by the Fishery Steering Committee on 11/02/01; chair of the Ecosystem Modeling Advisory Panel is Dr. K. Sellner) composed of several scientists and policymakers closely involved with ECOPATH to oversee and coordinate model development and progress
- NCBO and others will identify chairmanship of four working groups on data refinement and model development, fishery policy guidance, model responsiveness and consistency with historical observations, and linkages to water quality (accepted by the Fishery Steering Committee, 11/02/01). Proposed chairs include Dr. R. Latour, Mr. J. Uphoff, and Dr. M. Kemp who, in turn, will select workgroup members.
- NCBO and UBC will schedule an intensive ECOPATH training workshop for 15-25 participants for the late winter, to provide expert guidance on the use of the models.
- NCBO and UBC will schedule the second ECOPATH with ECOSIM Workshop for April or May to inspect and refine the Chesapeake Bay ECOPATH model developed in winter/early spring.
- All participants interested in model development must identify the best data for model input, continue refining the estimates, and evaluate and prioritize a set of Chesapeake 2000-related policy questions to test in the model.
- Within 12 months, NCBO and others will develop a technical report on EwE progress.

Workshop Accomplishments

Overall, the workshop was a success, leading acting NCBO Director Bahner to note that according to the UBC modelers, "We have accomplished in two-and-a-half days what it takes most groups four-and-a-half months to accomplish." Specifically:

- A diverse community of modelers, researchers, and policymakers, initially skeptical, assembled and agreed upon an initial data set for input to the ECOPATH Chesapeake Bay model.
- A balanced Chesapeake Bay ECOPATH model was produced, indicating that initial biomass, composition, and turnover rates do not violate basic thermodynamic mass balance equations.
- Dynamic simulations using a Chesapeake Bay ECOSIM model were initiated.
- By adjournment, participant enthusiasm for the ECOPATH with ECOSIM modeling approach resulted in community recommendations for a modeling

oversight/advisory panel and four specific workgroups to undertake the next difficult steps.

- A minimum of 15 participants requested additional intensive, hands-on training in ECOPATH modeling.
- Linking water quality activities in the CBPCBP through the model is critical to future success and acceptance by the regional community, thereby filling needs for the living resources and the historically-supported water quality modeling efforts in the CBP.

Areas of concern that should be addressed in future communications include the mechanism for modeling more than two (juvenile and adult) life stages, seasonal versus annual output, spatially-explicit EwE results (Bay segments versus whole Bay), and the linkage of the historically dominant bottom-up CBP Water Quality Modeling activities and results to the top-down approach exemplified in EwE modeling.

Finally, throughout the next nine months, the Chesapeake Bay ECOPATH with ECOSIM models and identified data sets will be distributed to meeting participants on receipt from UBC. The NCBO encourages open use of the models and can be contacted for distribution of model software, data, and training materials.